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THE TIDAL POWER RESOURCES OF THE INCHON BAY, KOREA

By Tae Sang WON,
Ph. D., C. E., D. Eng.,
Professor and Chairman,
Department of Civil Engineering,
College of Engineering,
Seoul National University,
Seoul, Korea,
Member, National Academy of Sciences,
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by

Tae Sang Won, Ph.D., C.E., D.Eng.,
Professor and Chairman,
Dept. of Civil Engineering
College of Engineering
Seoul National University

Seoul, Korea
Member, National Academy of Sciences
Republic of Korea

I. INTRODUCTION

It is obvious that nations which enjoy the benefits of civilization today must develop power sources to create modern industries. This is especially true for a country such as the Republic of Korea. Electric power resources in the Republic of Korea, unfortunately, remain much less than the demand because Korea has been separated into two parts since 1945 - the north with substantial sources of power developed before that date, and the south, where the Republic of Korea Government has striven earnestly during the past seventeen years to develop new power resources.

Natural sites capable of being developed as power sources are plentiful in Korea. Among these natural resources, the world famous high tides of Inchon Bay on the western coast of Korea offer one large potential source of power. Tides in this region have a maximum range in excess of ten (10) meters. Substantial development of these tidal power resources should be capable of producing more than 2,000,000 K.W. of electricity.

II. TIDAL POWER RESOURCES OF THE REGION NEAR THE INCHON BAY

1. The Record of the Tidal Range in the Region and its Localities.

In the regions of the western coast of the Korean Peninsula, the tidal range is generally great. Especially in the regions near the Inchon Bay, between the districts of about 160 kilometers from north to southward, it is world famous in the point what the tidal range is extremely great. As the horizontal distribution of this district Table 1 which shows the tidal range and others at the various regions including islands, is shown here.

Table - 1

Value of the Tidal Ranges at the Regions Near the Inchon Bay

Region	Average H.W. interval	Tidal rise	Tidal range	Neap range
Mohang-ni	3^h : 34^m	6.51^m	5.88^m	2.82^m
Umu island	4 : 06	7.68	7.02	3.36
Soya island	4 : 17	7.41	6.72	3.12
Tokchok island	4 : 11	7.50	6.78	3.00
Daemui island	4 : 24	8.22	7.56	3.42
Asan (Hanjin)	4 : 25	8.79	8.10	3.84
Inchon harbour	4 : 32	8.58	7.98	3.54
Jumun island	4 : 48	7.95	7.26	3.36
Estuary of the Han River	--	9.60	9.00	--

The annual record of the tidal range at the Inchon harbour is illustrated in Table - 2.

According to Table - 2. the annual records show as follows:

Annual Max	10.4
Annual Min	2.9
Annual Average	6.2

The reason what the tidal range in the region near the Inchon Bay is extremely great may be described as follows. The tide, a sort of wave created in the deep ocean proceeds to the Yellow sea through the Ryukyu Islands, and proceeds to the Pohai Bay after passing the western coast of Korea and dragging the southern part of the Liaotung peninsula. When the wave reaches the western coast of Korea, the depth of the water in which it travels, suddenly becomes very shallow and also the width of the water surface becomes narrow and assumes a conical shape. Consequently, it appears that the phenomena of extra-high tidal ranges in Inchon Bay are due to the topographical and geographical locality of the region. It takes the tidal wave about 9 hours to get to Inchon Bay from the Ryukyu Islands. It appears that the mean tidal range is about 1.5m in the region of the Ryukyu Islands. Gradually, it increases in value as it travels north ward and local conditions then make it appear extra-large in the Inchon Bay region.

Table - 2

Annual Record of the Tidal Range at the Inchon Harbour
(unit in meter)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1 am	---	4.1	---	4.3	5.8	7.5	7.0	7.3	8.1	7.9	7.1	6.7
pm	3.5	4.4	3.7	5.3	6.6	7.7	7.0	7.1	7.5	8.2	8.2	8.3
2 am	4.3	4.8	3.8	5.6	7.1	8.1	7.5	8.8	8.1	7.8	6.5	6.1
pm	4.0	5.5	4.0	6.7	7.7	8.1	7.4	6.8	7.6	8.1	7.7	7.7
3 am	4.7	5.9	4.2	7.2	8.2	8.4	8.9	8.2	7.9	7.4	5.8	5.6
pm	4.9	6.8	5.2	8.1	8.5	8.2	6.6	6.9	7.5	7.8	7.1	7.0
4 am	5.5	7.1	5.6	8.6	9.1	9.2	8.5	8.0	7.3	6.7	5.0	5.0
pm	6.0	8.0	6.6	9.1	9.1	7.3	6.6	6.9	7.1	7.2	6.1	6.0
5 am	6.4	8.2	7.1	9.5	9.3	9.0	8.3	7.6	6.6	5.8	4.1	4.5
pm	7.1	9.1	8.1	9.6	8.6	6.9	6.4	6.7	6.5	6.5	5.3	5.3
6 am	7.3	8.2	8.5	9.4	9.9	8.5	7.9	6.1	5.7	4.8	3.7	---
pm	8.1	10.2	9.2	9.8	9.3	6.4	6.2	6.3	5.8	5.6	---	4.6
7 am	8.1	8.8	9.5	10.2	9.6	7.9	7.2	6.4	4.7	3.7	4.4	5.2
pm	9.0	10.3	9.4	9.4	7.7	5.8	5.8	5.8	5.1	4.8	4.0	5.1
8 am	7.7	9.0	9.6	9.9	8.9	7.0	6.5	5.4	3.6	3.0	5.0	5.8
pm	9.8	10.1	10.4	8.5	6.7	5.0	5.3	5.1	4.4	---	5.1	6.0
9 am	7.9	8.8	9.9	9.1	7.9	6.0	5.7	4.4	---	3.9	6.2	6.8
pm	9.9	9.1	10.0	7.3	5.6	4.4	4.8	4.5	3.5	3.8	6.6	7.1
10 am	7.9	8.1	9.6	7.9	6.7	5.0	4.9	3.6	3.8	4.9	7.4	7.5
pm	9.5	7.8	9.1	5.8	4.6	3.9	4.3	---	3.9	5.2	7.9	8.0
11 am	7.6	7.2	8.8	6.6	5.5	4.2	4.2	3.5	4.8	6.2	8.4	8.2
pm	8.6	6.3	7.7	4.4	3.7	---	---	3.9	5.1	6.7	9.0	8.6
12 am	7.0	6.1	7.8	5.1	4.4	3.3	3.6	3.9	6.2	7.7	9.1	8.5
pm	7.5	4.7	6.1	3.2	3.1	4.2	4.3	4.3	6.5	8.2	9.6	9.1
13 am	6.3	5.0	6.4	4.0	---	3.6	3.7	4.9	7.5	8.7	9.3	7.6
pm	6.1	---	4.6	---	3.7	4.6	4.5	5.2	8.1	9.4	9.5	9.6
14 am	5.5	4.0	5.0	2.9	3.1	4.2	4.8	6.1	8.2	9.7	8.6	7.4
pm	4.9	3.6	3.2	3.4	4.1	5.1	5.0	6.4	9.2	10.1	10.1	9.2
15 am	---	3.8	---	3.2	3.8	5.0	5.3	7.4	9.5	9.3	8.0	8.3
pm	4.4	4.0	3.2	4.1	4.8	5.6	5.7	7.6	9.4	10.4	9.5	8.5
16 am	4.7	4.3	3.1	4.1	4.6	5.8	6.4	8.4	10.2	9.7	7.2	6.3
pm	4.4	4.8	3.5	5.1	5.5	7.2	6.5	8.6	9.9	10.2	8.5	7.6

Table - 2 (Cont'd)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
17	am	4.7	5.0	3.6	5.1	5.6	6.7	7.2	9.6	10.0	8.8	6.1	5.6
	pm	4.9	5.7	4.4	6.0	6.3	6.8	7.4	8.6	9.9	9.6	7.3	6.5
18	am	5.2	5.8	4.5	6.1	6.4	7.4	8.1	10.1	9.3	7.7	5.0	4.8
	pm	5.6	6.6	5.3	6.8	6.9	7.3	8.1	8.9	9.3	8.5	5.9	5.4
19	am	5.8	6.6	5.5	6.9	7.1	8.9	9.2	9.9	8.1	6.2	3.9	4.2
	pm	6.3	7.2	6.3	7.3	7.4	6.7	7.6	8.9	8.2	7.0	4.8	4.4
20	am	6.4	7.1	6.4	7.6	7.7	8.9	9.6	9.3	6.5	4.7	3.3	3.7
	pm	7.0	8.4	7.1	8.8	7.7	7.0	7.9	8.5	7.0	5.6	3.9	---
21	am	6.9	7.1	7.1	8.5	8.8	9.0	9.5	9.3	5.0	3.5	---	4.1
	pm	8.3	8.3	7.6	7.6	7.1	7.0	7.8	7.7	5.6	4.4	---	3.3
22	am	6.4	7.4	8.0	8.4	8.8	8.7	8.9	6.8	3.5	---	4.1	4.1
	pm	8.2	8.2	7.9	7.6	7.0	6.7	7.4	6.7	---	3.0	3.7	3.7
23	am	6.7	7.6	7.9	8.6	8.6	7.2	8.0	5.4	3.6	3.6	5.6	4.6
	pm	8.2	8.0	8.1	7.3	6.6	6.2	6.9	5.6	3.3	3.3	4.5	4.5
24	am	6.8	7.4	8.2	8.2	8.2	7.4	6.7	4.0	3.7	4.3	5.4	5.2
	pm	8.0	7.5	8.0	6.7	6.1	5.7	6.2	---	3.6	4.1	5.4	5.3
25	am	6.7	7.1	8.2	7.8	7.5	6.4	5.6	3.9	4.5	5.1	6.1	5.8
	pm	7.7	6.8	7.6	6.0	5.4	5.4	5.6	3.9	4.5	5.2	6.2	6.2
26	am	6.5	6.5	7.9	7.1	6.7	5.6	---	4.1	5.4	6.0	6.7	6.5
	pm	7.0	5.9	6.9	5.0	4.8	---	5.0	4.2	5.5	6.1	6.9	7.0
27	am	6.1	5.8	7.3	6.2	5.9	5.0	4.6	4.9	6.4	6.7	7.1	7.1
	pm	6.2	4.7	6.0	4.1	4.5	5.4	4.8	5.0	6.4	6.8	7.4	7.7
28	am	5.5	5.1	6.5	5.3	---	5.2	4.8	3.7	7.1	7.3	7.4	7.5
	pm	5.3	3.7	4.9	3.7	5.2	5.7	5.1	5.8	7.2	7.5	8.5	8.7
29	am	4.9	---	5.6	---	4.8	5.7	5.4	6.5	7.6	7.7	6.9	6.9
	pm	4.4	---	3.9	4.7	5.6	6.2	5.7	6.6	7.7	7.8	8.6	9.0
30	am	4.5	---	4.9	4.5	5.6	6.4	6.2	7.2	8.5	8.1	6.9	7.1
	pm	3.6	---	---	5.5	6.3	6.7	6.2	7.2	8.0	8.4	8.5	9.0
31	am	---	---	3.7	---	6.5	---	6.8	8.7	---	7.3	---	7.0
	pm	3.7	---	4.3	---	7.1	---	6.8	7.2	---	8.4	---	8.6
max		9.9	10.3	10.4	10.2	9.9	9.2	9.6	10.1	10.2	10.4	10.1	9.0
min		3.5	3.6	3.1	2.9	3.1	3.9	3.6	3.5	3.3	3.0	3.3	3.3
aberage		6.4	5.6	6.6	6.5	6.5	6.5	7.1	6.5	6.6	6.7	6.6	6.5

Topographical or geographical characteristics of the region near the Inchon Bay, are illustrated by the following facts. The sea shore of the region had been created by the sinking of the land for a long time in the past. For this reason, we can establish the fact that there are numberous zigzags in the sea shore line, innumerable islands, the depth of water is generally very shallow, the topography of the region forms a conical shape and creates numerous creeks. It seems to the author that these topographical or geographical localities account for the extremely high ranges of tide is the region.

2. Selected Tidal Power Sites and Estimated Output.

As stated above, in the regions near the Inchon Bay, there exists numerous good conditions to develop the tidal power resources in the topographical and geographical localities having an extra-large tidal range. Therefore, it may be said that there are numerous good tidal power sites in the regions near the Inchon Bay.

Among these, a project of the Kangwha Island established by some Japanese engineers in earlier days (about 1923) is illustrated briefly in Table - 3. In this project, the following data were adopted.

(a) Location of the Projects Site:

The district surrounded by the sea shore of Hado-Myun and Kilsang-Myun, Kanghwa County, Tongkom Island, Seo Island, Yongchong Myun, Puchon County, and the Hwangsam Island, Kimpo County.

(b) Tidal Range:

By the record of 1923
For rising tide: max 9.78 m , min 3.06 m
For ebb tide : max 9.45 , min 3.45

There are 6 projects (A, B, C, D, E, F) by the type of the systems, number and capacity of the tidal reservoirs etc.

We can recognize by Table-3 that it would be profitable to adopt the project E or F - single reservoir system-than the others to get cheaper and a more plentiful amount of electric power, even though there may be inconvenience in the point of unequal and intermittent production in the size of the produced electricity. (Vide Fig. 1)

In addition to the region near the Kanghwa Island mentioned above, there are numerous good tidal power sites in the western coast as stated above. Above all, the following sites are considered to be good sites to develop sooner or later, and reconnaissance, partially actual surveys, and also partially geological survey were made for them by the Korea Electric Power Company several years ago. Some French engineer was joined in the recommaissance. These data are illustrated in Table - 4. The producible outputs were also estimated as the values in Table - 4. (Vide fig. 2)

Table - 3

Tidal Power Project at the Region Near the Kanghwa Island

Type of Systems	Double Reservoir System				Single Reservoir St.	
	A	B	C	D	E	F
Number of Reservoirs	2	2	2	2	1	1
Total Area of Reservoirs (Chongbo)*	2,498	1,511	1,511	1,511	1,511	1,511
Higher Reservoir	776	776	776	776	--	--
Lower "	735	735	735	735	--	--
Spare "	985	--	--	--	--	--
Avilable Head (m)	10.5-6.75	1.95-5.85	1.8-5.4	1.8-5.4	1.8-5.4	1.8-5.4
No. of Turbines (Set)	56	20	8	8	20	20
Output Capacity						
max (M.W.)	10.425	9	36.12	21.12	47	47
normal	7.5	6.5	15	17.6	44	44
average	4.5	4.8	21.12	7	11	11
Annual Producible Power (1,000KWH)	39,420	42,048	185,022	61,320	96,360	96,360
Total Cost ($1000)	4,225	2,250	4,325	2,750	4,000	4,270
Unit Cost ($ per K.W.)	544.5	346	Steam 105 Tidal 165.5	156.5	91	97
Maintenance annual Cost ($1000)	119.5	83	1,248.26	125	150	150
Profit Apportionment(%)	10	10	10	10	10	10
Necessary Electric Rate (Cent/K.W.H.)	1.4	0.735	0.85	0.655	0.57	0.6

* 1 Chongbo equals to 1 hectare approximately.

Table - 4

Producible Outputs for the Selected Sites

	Name of Sites	No. of Proposed Reservoirs	No. of Gauge Stations	Productible Outputs(K.W.)
a	Sihung	2	2	113,000
b	Namyang	2	2	61,000
c	Tangjin	1	1	125,000
d	Karorim	1	1	163,000
e	Asan & Punhyang	1	1	174,000
f	Anhung	2	2	104,000
g	Sosan	1	1	15,000
h	Chonsu			347,000
	Kanghwa-Inchon			200,000
	Total			1,302,000

Geological survey were made at the sites of Asan and Punhyang. Describing briefly the results, the geological formation generally consists of 3 - 6 m of topsoil and clay, 2 - 4 m of sand and gravel layer, 3 - 6 m of soft and crushed rock, 4 - 9 m of hard rock bed below of the bottom of the sea. Therefore we can find the rocky bed at the depth of 8 - 16 m below of the bottom of the sea. Henceforth it may be said that the geological condition is also very favourable to construct dams with cheaper cost.

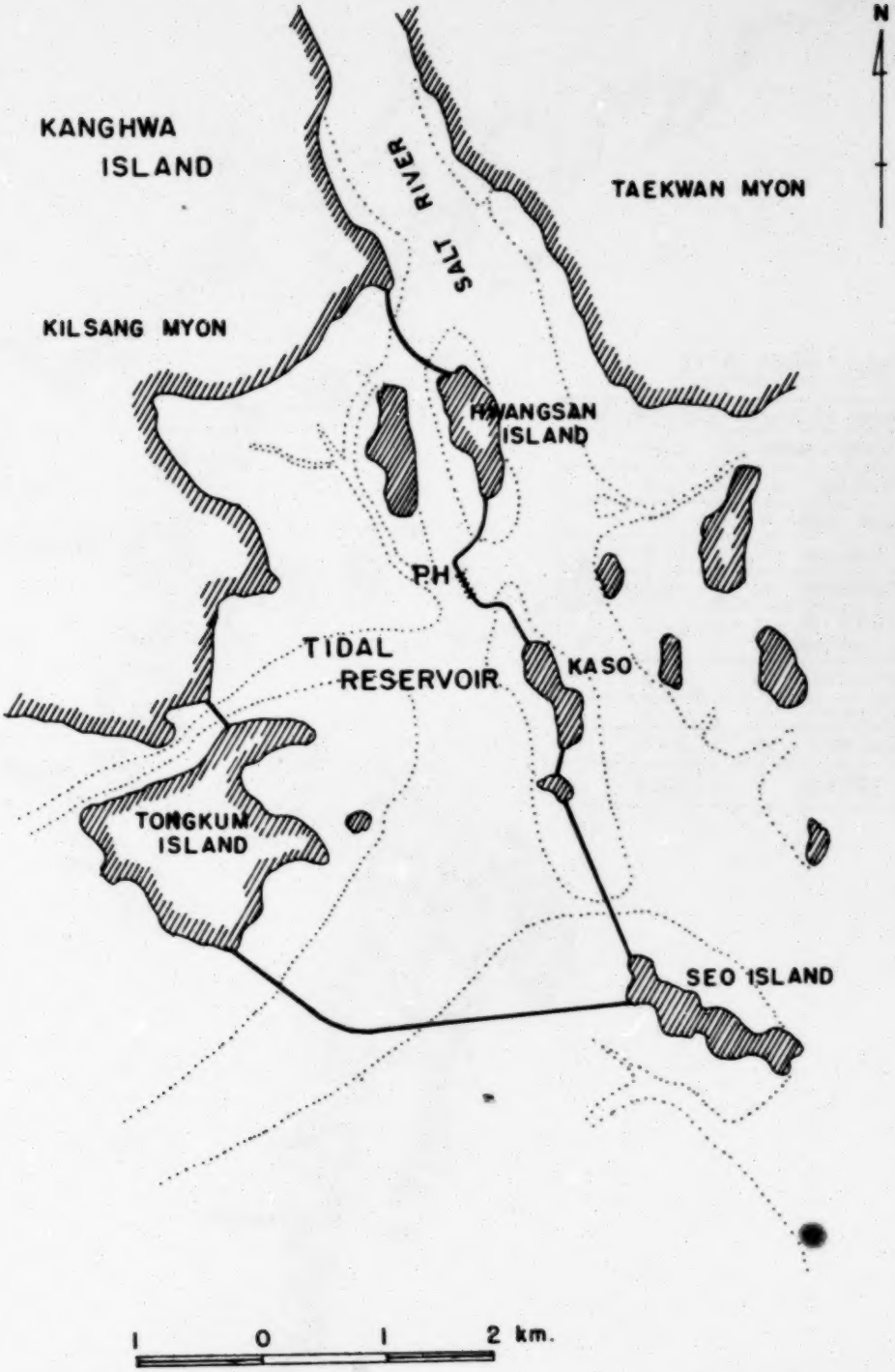
III. CONCLUSION

As natural power-resources in Korea, of course, the water power resources of the rivers would be considered to be promising. But the most parts of the excellent water power sites are located in the North Korea. Moreover, it is necessary to construct high dams and to build large reservoirs as far as possible to develop the water power sites in Korea viewing the meteorological and hydrological characteristics of the rivers in Korea. To develop the water power sites in such a manner, it needs huge amount of money, and on the other hands, it produces a reduction in cultivated land. This is a serious problem in an agricultural country like Korea. Also when high dams and large reservoirs are constructed in a locality such as Korea, the output decreases suddenly or falls to zero during the "winter or summer dry season". Therefore, electric power rates in Korea are necessarily higher than in other countries.

On the contrary, in the tidal power generation, we can eliminate the effects of a sudden decrease of output during the winter or summer dry season, even we feel the deficiency of the "unequal magnitude of the output" each hour.

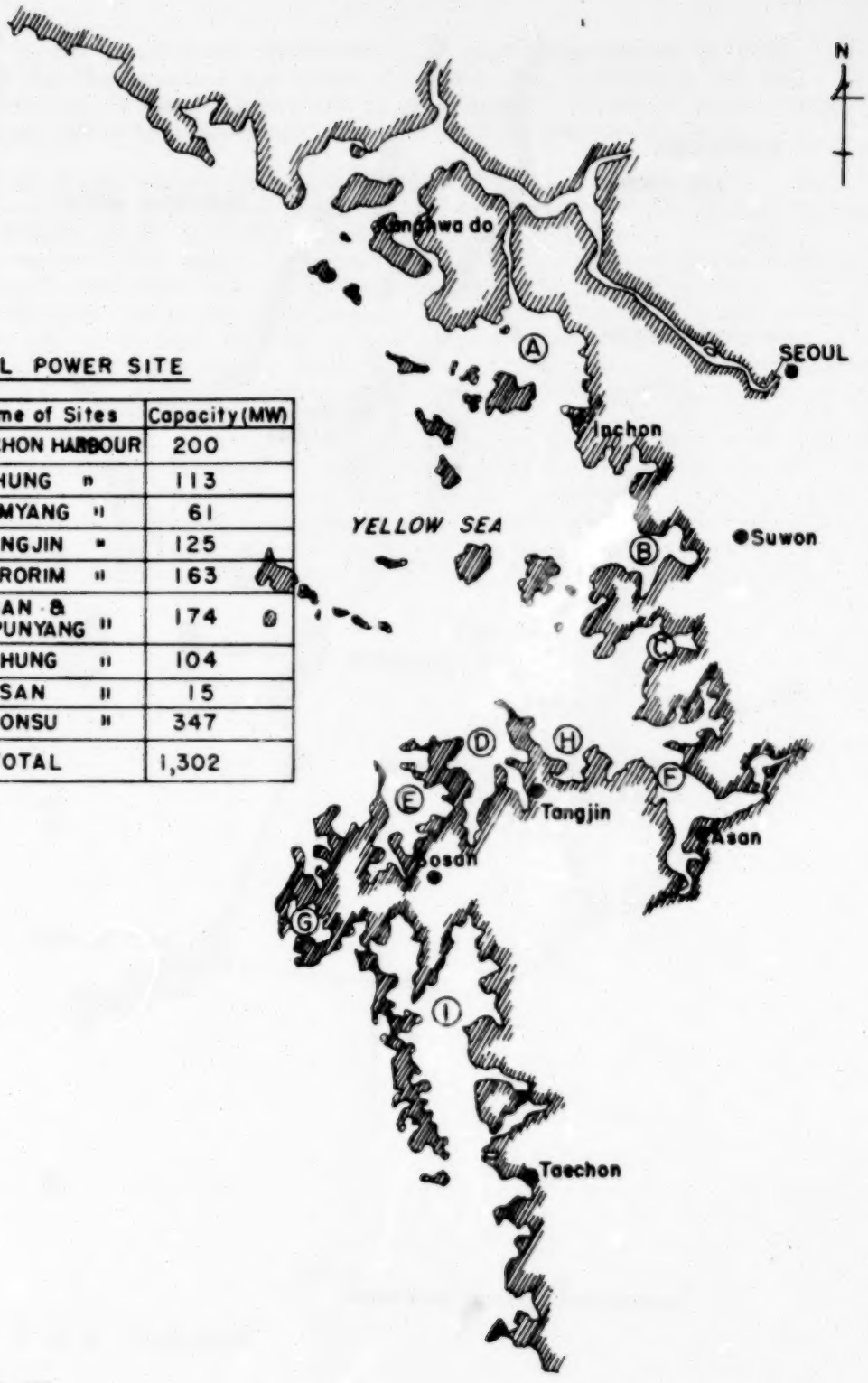
In the tidal power development, it needs huge amount of cost mainly for the construction works under the sea, especially for the construction of dams. Therefore it is necessary to select such a site where we can reduce the length of dams by its local conditions.

As stated above, the western coast of Korea, particulary in the region from 160 kilometers above the northern shore of the Inchon Bay to the northern shore of South Chungchong Province, there is not only a world famous tidal range - greater than 10 m, but also adequate favourable local conditions i.e. numerous zigzags of the sea shore which forming adequate creeks and bays bearing innumerable islands in the estuary of the creeks or bays just as if forming a natural break-water. The depth of water generally is very shallow for a considerable distance from the shore. It would be sufficient to say that local conditions of the region near Inchon Bay would shorten the length of dams and reduce the construction cost, in other words, they would form excellent tidal power sites. Moreover, it seems to the author, that the construction cost would be cheaper because various new methods of construction and improved effective equipment including "Prepact Concrete" have recently been invented and developed. Therefore it can be said that these tidal resources sites are waiting for the world's attention to be developed in practice.



PROJECT E & F

FIGURE I



TIDAL POWER SITE

	Name of Sites	Capacity (MW)
A	INCHON HARBOUR	200
B	SIHUNG "	113
C	NAMYANG "	61
D	TANGJIN "	125
E	KARORIM "	163
F	ASAN & PUNYANG "	174
G	ANHUNG "	104
H	SOSAN "	15
I	CHONSU "	347
TOTAL		1,302

FIGURE II-

1322 E - Nov. 1962 - 1,600